

253850-16-F

Final Report
**Retrieval, Display, and Analysis Support Tool for Earth
Imagery**

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SEPTEMBER 1995

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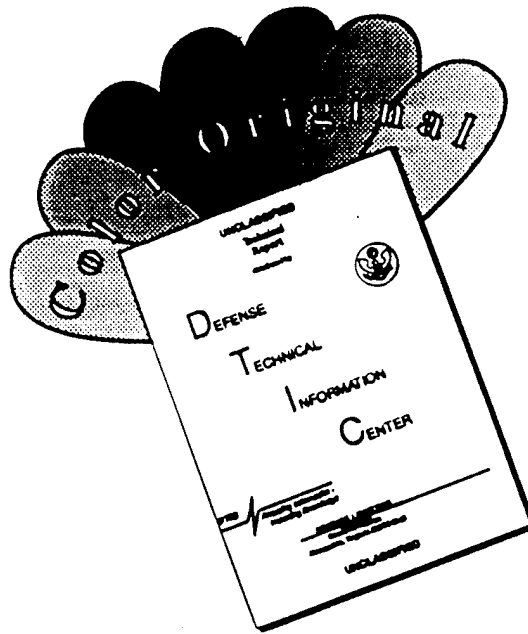
Contract Number: DLA900-88-D-0392
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REPORT DOCUMENTATION PAGE

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OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Final Report - 10/1/93 - 6/30/95	
4. TITLE AND SUBTITLE Retrieval, Display, and Analysis Support Tool for Earth Imagery			5. FUNDING NUMBERS	
6. AUTHOR(S) R. C. Anderson				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Environmental Research Institute of Michigan P.O. Box 134001 Ann Arbor, MI 48113-4001			8. PERFORMING ORGANIZATION REPORT NUMBER ERIM 253850-16-F	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Technical Information Center 8725 John J. Kingman Road, Suite 0944 Fort Belvoir, VA 22060-6218			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The Retrieval, Display, and Analysis Support Tool (RDAST) system is evaluated in terms of utility to the Special Operations Mission. RDAST is a combined analytical and computer based methodology for matching user needs with available earth imagery. Earth imagery from currently operational earth observation satellites has been incorporated into a geographic data base to provide the user sample imagery prior to acquisition of extensive datasets. RDAST could prove useful to Special Operations forces in a number of ways. Because imagery can be delivered over internet, in-theatre convert operations could still maintain access to data. While the images available from earth observation resources such as Landsat and SPOT lack the resolution for many applications, many Special Operations tasks may be fulfilled using system of this spatial resolution. For example, bathymetric surveys of littoral regions can be conducted with these image resources. In this case, the multispectral image data from SPOT and Landsat compensate for the lower resolution. This report also identifies specific improvement to enhance RDAST's utility to the Special Operations forces.				
14. SUBJECT TERMS Earth Resources Special Operations Multispectral Imagery			15. NUMBER OF PAGES 20	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited	

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Final Report

08/14/95

Report Number 253850-16-F

Retrieval, Display, and Analysis Support Tool for Earth Imagery

FINAL REPORT

September 1995

Submitted by:

Infrared Information Analysis Center
Environmental Research Institute of Michigan

To:

Defense Technical Information Center

This final report summarizes project activity over the period 10/01/93 to 06/30/95.

1. Introduction

DoD Components are being required to prepare plans to handle an increasingly broad spectrum of events across a proliferating number of geographic locations. In addition to preparing for military hostilities in territories adjacent to allied and friendly powers, DoD components now provide support to United Nations and other multilateral peacekeeping organizations, provide disaster assistance to new and emerging nations, provide military resources to aid in humanitarian assistance and provide support in operations short of war across the entire globe. DoD Components also provide support to ongoing efforts to monitor arms control agreements, arms embargoes, and environmental change.

Each of these activities gives rise to the need to collect and analyze data with respect to changing use of land resources. Earth imagery collected by national and commercial means has become a critical resource to aid DoD components in timely preparation and performance of their assigned roles, missions, and functions. Exploitation of available commercial and open source earth imagery can play an immensely beneficial role for DoD, enabling U.S. forces to discuss with foreign counterparts, contractors, citizens, and government officials the full nature of the situation of interest without compromising sensitive national technical means of arms control agreement verification or other similar information sources and analysis methods.

Special Operations Forces (SOF) conduct various peace time missions such as

Foreign Internal Defense, and Unconventional Warfare, requiring imagery. SOF are often without the requisite imagery support particularly for nations not included in the Defense Guidance Major Regional Contingencies. Availability of open source imagery could be vital to SOF units that deploy on short notice and do not have access to national level imagery. In particular, multispectral imagery could provide valuable information concerning vegetation and terrain features unavailable through intelligence assets.

The RDAST systems was developed to assist the potential user of earth observations and other imagery to identify, acquire, and analyze these images, extracting information needed to fulfill the users needs. Previously, requirements development was undertaken for dual-use oriented functions such as Federal Emergency Management Agency, in the case of crop and trafficability analyses related to the Midwest floods of 1993.

The worldwide availability of unclassified earth observation data provides a potential resource for special operations forces, if these data can be managed. The intent of this effort was to assess the utility of these databases in supporting the special operations mission.

2. Technical Summary

The Retrieval, Display, and Analysis Support Tools (RDAST) has been summarized in previous documentation submitted under this contract. Briefly, this application facilitates the user's access to a wide variety of imagery to support his particular needs. A simplified flow diagram of the RDAST system is shown below. Previous efforts have resulted in creation of the database query tool; in this work we concentrate on the requirements process to support the Special Operations mission.

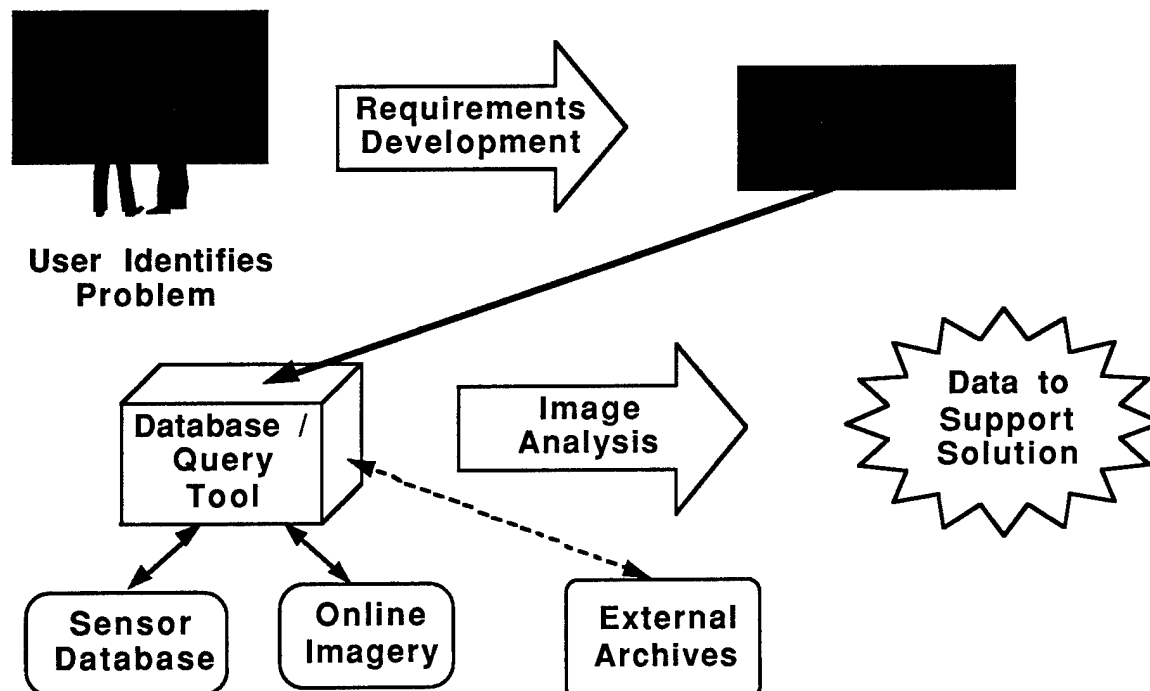


Figure 1

Previously, we developed strawman requirement for emergency assistance operations, such as might have been required by the Federal Emergency Management Agency in the Midwest flooding of 1993. The methodology used is illustrated below:

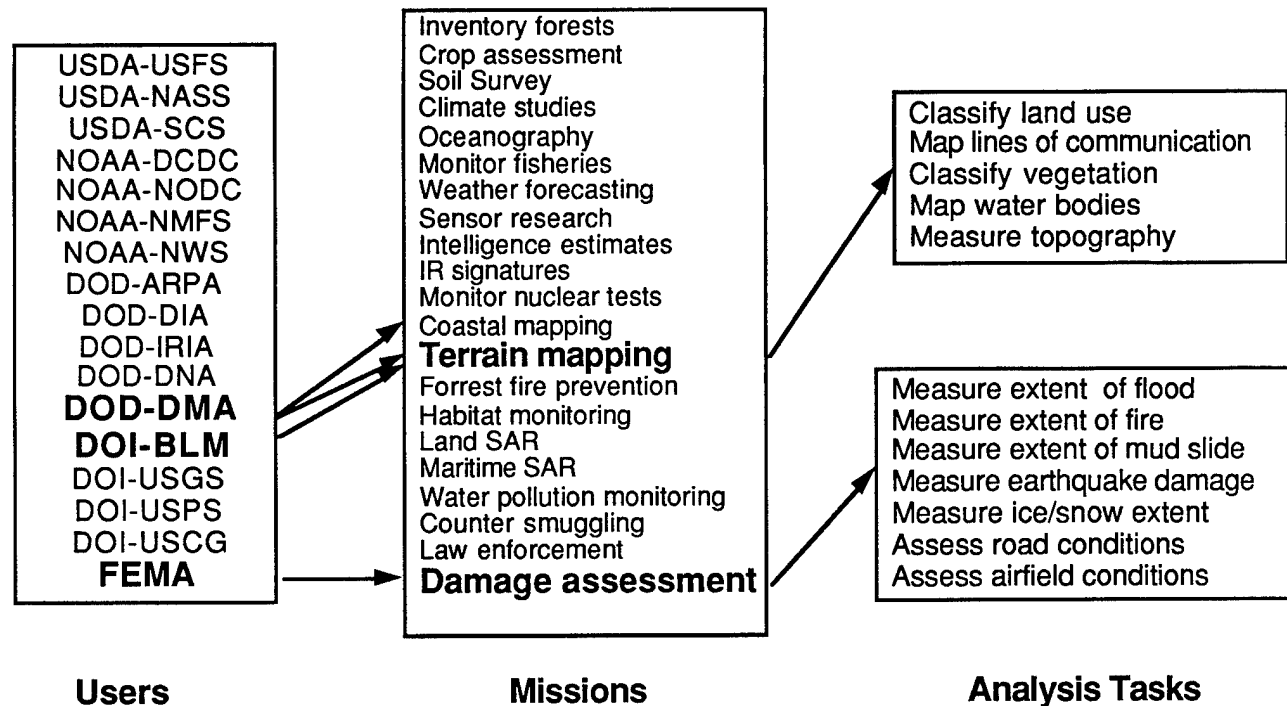


Figure 2

The domain of possible users is represented by the block list on the left. Three candidate users agencies have been highlighted: Department of Defense Defense Mapping Agency; Department of the Interior Bureau of Land Mangement, and the aforementioned Federal Emergency Management Agency. These agencies are then mapped into candidate missions; note that a single agency may encompass more than one mission, and that a single mission may be carried out by more than one agency.

The next step is the conversion of missions into specific analysis task, enumerated in the third column here. In the Midwest flood example, the extent of flooding, road conditions, and other analysis tasks are brought into play.

3 Special Operations Background

United States Special Operatrions Forces are designed be deployed in flexible force packages to minimize national risk and maximize strategic advantage.

They are specially trained, equipped, and organized, DoD forces intended for use against strategic or tactical targets in pursuit of national military, political, economic, or psychological objectives. Special operations may be conducted during peace or

hostilities. They may support conventional operations, or may be prosecuted independently when the use of conventional forces is inappropriate or infeasible.

3.1 SOF Missions

Five primary missions are associated with SOF¹. These include:

- **Foreign Internal Defense (FID):** The primary role of SOF in this U.S. Government interagency activity is to train, advise, and assist host-nation military and paramilitary forces to assume responsibility to eliminate internal instability. FID operations foster internal development of the economic, social, political, and military segments of a nation's structure.
- **Special Reconnaissance (SR):** Special Reconnaissance complements national and theater intelligence collection systems by obtaining specific, well-defined, and time-sensitive information of strategic or operational significance. SR operations place U.S. or U.S. -controlled "eyes on target" in hostile, denied, or politically sensitive territory when authorized. SOF may conduct SR missions unilaterally or in support of conventional operations.
- **Direct Action (DA):** In the conduct of DA operations, SOF units may employ raid, ambush, or direct assault tactics. SOF may emplace munitions and other devices; conduct stand-off attacks by fire from air, ground, or maritime platforms; provide terminal guidance for precision-guided munitions, and conduct independent sabotage.
- **Counter terrorism (CT):** The primary mission of SOF in this interagency activity is to apply highly specialized capabilities to preempt or resolve terrorist incidents abroad.
- **Unconventional Warfare (UW):** UW includes guerrilla warfare and other low visibility, covert, or clandestine operations, as well as subversion, sabotage, intelligence collection, and evasion and escape (E&E).

Additional assigned missions include psychological operations (PSYOPs), civil affairs activities, and collateral special operations activities that support both general purpose forces and special operations. PSYOPs and CA generally do not involve imagery. However, collateral activities in which SOF, by virtue of their inherent capabilities, selectively may be tasked to participate include: security assistance, humanitarian assistance, anti terrorism and other security activities, counter drug operations, personnel recovery, counter proliferation of weapons of mass destruction, and special activities, all requiring overhead imagery.

Special Operations missions are distinguished from conventional military operations in the following ways.

- **One-time Opportunity:** Special Operations missions, particularly counter

¹Department of Defense Joint Publication 1-02

terrorist or hostage recovery contingency operations, must seize the appropriate moment for complete success. Their very nature dictates they be done right the first time, every time. Strategic and tactical windows of opportunity are limited and of short duration. Because of the sensitivity of the operations, the penalties for failure, both political and military, are costly.

- **Unorthodox Approaches:** Special Operations does not negate the traditional principles of war. Rather, it places a different emphasis on their combination or importance. For example, in a SO mission, surprise achieved by speed, stealthy, audacity, deception, and new tactics or techniques can be far more effective and efficient than a conventional force using traditional tactics.

- **Unconventional Training and Equipment:** The unusual demands of a SO mission define the training and equipment required. Often, attaining the SO objective calls for a unique mixture of specialized skills and equipment that may be outside the scope of conventional forces.

- **Political Sensitivity:** Virtually every aspect of a SO mission is constrained by the politically sensitive context in which it is conducted. For instance, the cultural mores of a country may dictate a low-visibility profile operation, while larger political considerations may require a visible presence in an advisory capacity at the national level.

- **Need for Special Intelligence:** SO missions, intelligence driven and intelligence dependent, require immediate and continuous access to information from traditional as well as nontraditional sources. SO generally relies on formal intelligence structure, but, for certain sensitive mission, tactical and operational information must be developed using SOF assets such as advance or reconnaissance forces.

Highlighted by the last requirement but common to all, is the need for imagery. Because SOF missions are often in areas not regularly served by battlefield systems or national sensors there is a lack of overhead imagery available for mission planning. The resources and capabilities of IRIAC could satisfy many of the imagery requirements.

3.2 SOF Imagery Requirements

Improved intelligence systems are a SOF priority. There is a critical deficiency in the ability of SOF units to receive and process near real-time intelligence from national and theater collection platforms. USSOCOM has undertaken a systematic identification of SOF intelligence requirements and shortfalls. Programs to satisfy these requirements and correct the shortfalls have been initiated. These projects include the Special Operations Command Research, Analysis, and Threat Evaluation System (SOCRATES); Man Transportable SOCRATES; a deployable SOF Intelligence Vehicle; SOF Imagery Receiver and Intelligence System; and the CONSTANT SOURCE intelligence dissemination system. All of these systems form mechanisms capable of putting the imagery into the soldier's hands. The missing component is imagery for areas frequented by SOF but not available within the

intelligence community. Additionally, large archives of images, the depth of information available from the multi-spectral data files resident at ILIAC and the analysis capability of ILIAC personnel could be the source of valuable insights for SOF.

SOF imagery requirements stem from a need for rigorous mission planning. The depth of information desired by SOF to effectively plan a direct action mission generally exceeds the available assets. SOF mission planners are interested in vegetation, traffic patterns, ingress and egress routes, and terrain data. Alternative sources of imagery in both areas of coverage and spectrum would provide SOF with the best assets available. In many cases this would be the only imagery available. Imagery available from intelligence sources is of very high resolution but is usually only in black and white. Many times intelligence imagery is not available for areas where SOF operate particularly during FID missions.

RDAST operates primarily with archival data. It cannot address the need for near real-time imagery intelligence. Even for new collections, civilian satellite imaging systems are generally not well suited to the fast turnaround that SOF is likely to require. The strong suit of RDAST is to identify unique sources of information and the value added by special processing and analysis, not readily obtainable via national and theater intelligence systems.

The true color, multi spectral, change, mosaics and thematic mapper images available, would meet SOF requirements for maximum information on a mission area. SOF operators in the field should not be burdened with overly complex request procedures. Their access must be facilitated as much as possible. To that end the following recommendations are provided as suggested enhancements to the Retrieval, Display and Analysis Support Tool (RDAST) already developed by IRIAC.

4. Conclusions Recommendations

There are a number of imagery products demonstrated by IRIAC and within RDAST which are likely to be of interest to SOF. The products likely to be of frequent use to SOF are:

- **Bathymetry:** Naval Special Warfare forces are required to conduct hydrographic reconnaissance of potential beaches for amphibious assaults. Multispectral imagery offers a capability to produce approximate contours for beaches not recently charted or where sand bars develop. This information would allow SOF planners to concentrate on areas with high probability of being suitable for the amphibious landing.
- **Change images:** Change images generated from LANDSAT data would be useful for determining new activity in a area selected for a mission. New roads, building construction, vegetation changes, changes in shoreline configuration, flooding and drainage may all be discerned from this type of analytically enhanced product.
- **Thematic Mapper:** Data from this source can provide a wealth of information on terrain features, vegetation classification and density, locations

of clearings and population centers, large heat sources and temperature variations such as from an industrial smokestack or cooling pond.

• **Multisensor Merging:** Merging images from synthetic aperture radar, high resolution photography and multi band data from SPOT can provide SOF with an enhanced ability to analyze targets. A high resolution black and white image can be 'colorized' using lower resolution imagery from a multispectral system to assess whether vegetation is suitable for providing concealment, recent traffic flow through an area or whether or not a building is in use. Merging a SAR image with an optical image can provide insight in a building's construction. SAR may also highlight security fences, power lines and antennas.

• **Synthetic Aperture Radar /Topography:** SAR data would be useful when processed to provide near 3-dimensional representations of SOF areas of interest. Much of the area of interest to SOF planners is not well mapped because it is cloud covered most of the time. SAR penetrates clouds. Interferometric techniques exist for producing very accurate terrain relief data from SAR imagery. These can then be displayed as a 3-D image or as a Digital Elevation map on which the SAR image or other types of imagery (when available) can be draped to produce a 3-D model of the terrain.

The imagery products have varying degrees of applicability to all SOF missions (summarized in Table 1):

Imagery Products	Bathymetry	Change Images	Thematic Map	Merged Imagery	SAR Derived Topography
SOF Missions					
Foreign Internal Defense (FID)	Moderate	High	Moderate	Low	Moderate
Special Reconnaissance (SR)	High	Moderate	Moderate	Moderate	High
Direct Action (DA)	Moderate	Moderate	Moderate	Moderate	Moderate
Counter terrorism (CT)	None	Low	None	Low	None
Unconventional Warfare (UW)	Moderate	Moderate	Moderate	Low	Low

Table 1

• **Foreign Internal Defense (FID):** While primarily concerned with the training of the host nation's internal security personnel, FID operations also foster internal development of the economic, social, political, and military segments of a nation's structure. All five of the imagery products listed above offer valuable insights into economic development.

- Bathymetry is needed to assess navigability of rivers, ports and harbors.
- Change images are particularly useful in assessing population growth,

agricultural and forestry activity and improvements (or decay) of infrastructure (roads and bridges). In many cases, they can also be used to assess damage due to war or natural disasters.

- Thematic Maps are useful in assessing national land use and infrastructure.

- Merged Imagery can provide information about cover and security measures at a site, but since FID operations usually provide access to the site this could just as well be performed at the site.

- SAR Topography can map areas not otherwise possible. It can also be used to assess ingress and egress to a site for the purpose of identifying weak points in a site's security (as stated above, in the context of FID this task could also be performed on site).

- **Special Reconnaissance (SR):** All five product types could provide some inputs into planning an SR mission.

- Bathymetry would be useful if ingress or regress were to be via a shoreline or river.

- Change Images would help identify areas of activity (to be avoided).

- Thematic Map could identify population centers, lines of communication and forested areas.

- Merged Imagery could provide information about cover and security measures at the target

- SAR Topography can identify gullies and subtle terrain features offering unobserved ingress and egress in areas without sufficient vegetation.

- **Direct Action (DA):** All five image product types could be useful in the planning stage of a DA operation.

- **Counter terrorism (CT):** The image products would have little or no utility in conducting the CT mission other than planning an SR mission in support of a CT operation.

- Change images could conceivably help detect a new training facility provided there were collateral information to initiate a search and other supporting evidence to confirm it.

- Merged Imagery might help identify a suspect facility if it possessed suspicious features like a security fence and unusual communications equipment.

- **Unconventional Warfare (UW):** All five product types could have some

utility in preparing escape and evasion plans and charts.

4.1 Recommended Modifications to RDAST

In order to be useful to SOF organizations several issues would first have to be addressed:

A. Port to PC Environment: RDAST currently runs on a Sun UNIX Workstation. Most SOF units do not have Sun workstations. Access from the units must be compatible with PC machines of modest capability. This includes the ability to download in TIFF or PICT formats readily usable with PC software.

B. Refine User Interface: The current user interface was built only a proof of concept and is not friendly enough for an inexperienced person to easily open, access and download images. The typical SOF individual accessing the system may not have any training in UNIX and will most certainly not have training on RDAST itself. From the opening screen the interface must lead the SOF operator through a logical progression from geographical area of interest, to size of image, type of image, any unique requirements, restrictions on databases to be searched, and procedures for downloading. The process must all follow intuitively. Macros for common formats should be developed to minimize operator quandary over bands to be selected and resolutions.

C. Links to other databases must be seamless to the SOF operator. If there is no imagery available within the IRIAC database, guides to other potential sources should be provided via HTML. Where those data bases are technically complex a shell should be provided to allow individuals unfamiliar with technical aspects to determine if there is an image of relevance available. Other nation assets; French SPOT, European Space Agency ERS- 1 Synthetic Aperture Radar mapping of the entire earth, the Canadian RADARSAT and perhaps the Russian overhead imagery files, could provide data on areas not covered by normal surveillance systems. Access to these should be as easy as the existing interface with the Global Land Information System (GLIS).

C. Populate the database. The database as currently exists is populated with a few images for in-house demonstration purposes. Before it is presented to SOF it must be fleshed out with at least one complete set of images for an area of current SOF interest such as Malaysia.

E. Images from multiple sources must be able to be geocoded and orthorectified with drag and drop ease.

F. A brief tutorial on terminology, benefits of different sensors or bands, and analysis services available from IRIAC should be accessible from the opening screen.

G. RDAST operation must be made "bulletproof." The SOF operator should never experience a crash or system lock-up. It takes only one instance of this and the field units will not use the system again.

H. Billing must be transparent to the operator in the field. The forward deployed units would not have to pay for the service. There would be a pre-negotiated level of support provided. USSOCOM would fund for a specified number of queries and man-hours of analysis. As the limit of that support was approached, IRIAC would negotiate with SOCOM whether an increase in funding would be appropriate or the service would be curtailed until the next fiscal year.

I. A method for providing access to IRIAC analytical skills and training should be embedded in RDAST. A simple hot link to a subroutine that generates an IRIAC support request would suffice. The capability would have to be restricted to certain requesters to preclude over tasking the IRIAC resources. Access to products like the ERIM data integration segment to manipulate images and combine with intelligence and tactical data keyed to specific military users will be vital in showing value added by IRIAC.

For RDAST to be useful it must be accessible by SOF units forward deployed. There are three methods to provide that accessibility. They are presented below in a building block approach that would allow USSOCOM access to the imagery for a modest investment. As the usefulness of the product is established, the support could mature into a fully integrated on-site infrastructure.

1. Internet gateway: An immediate means of providing the desired imagery to SOF would be to establish a Home Page on the World Wide Web that would be accessible by SOF units worldwide. Teams would dial in, establish their bona fides, navigate to the necessary images from the home page to the RDAST database and download the image directly. If further assistance or analysis were required the operator would log a request to be handled by the IRIAC support staff.

2. T1 line: The next level of support providing imagery to SOF would be to establish a T1 line access directly from the SOCRATES node at USSOCOM to the RDAST database at IRIAC. Units in the field would send their requests for imagery via SOCRATES. A SOCOM operator would process the query and relay it to IRIAC. IRIAC would generate the necessary image or analysis and provide it to USSOCOM via the T-1 line. The USSOCOM SOCRATES operator would then forward the image to the field unit. The level of support provided would encompass normal queries of the RDAST database as well as other databases accessible only through IRIAC links.

3. Direct on-site imagery support at USSOCOM: An individual provided by IRIAC on site in Tampa with a terminal linked to the RDAST database is the ultimate objective. This type of support would provide SOF with immediate access to both the database and analytical skills of IRIAC. IRIAC would be the window to the world for access to all other imagery databases. Requests for imagery support from forward deployed SOF units would come via the SOCRATES system. The operator would search the data base, locate the imagery available, manipulate the image or data as necessary to best display the required information and then transmit to the field user via SOCRATES.

Support of this nature would require the minimum amount of indoctrination or training of SOF units while providing the most responsive support. An additional benefit would be the operational security engendered by using existing secure communications links.

5 Summary

Access to the massive number of observations made of the earth's surface, oceans, and atmosphere by open source systems represents a significant resource which has not been fully exploited. SOF has a strong need for access to this information but that access must be user friendly and tailored to their needs. The information provided should assist IRIAC in generating a useful product to satisfy SOF's requirements.

APPENDIX: SAMPLE PHOTO PRODUCTS

IMAGE PROCESSING FACILITY SERVICES

Change Detection

MISSISSIPPI RIVER FLOODING St. Louis, MO



Landsat Satellite Thematic Mapper (TM) Change Image

Scene Dates: 15 July 86 Band 5 (Water Mask - Light Blue)
18 July 93 Bands 2, 4, 7 (Background Image)

0 10 Miles

This Thematic Mapper change image of the St. Louis, Missouri area indicates the dramatic effects of flooding along the Mississippi, Missouri and Illinois Rivers during the summer of 1993. TM data (bands 7, 4 and 2) from July 18, 1993 were geometrically corrected using **ERIM's Restoration** resampling technique to create the background image which shows flooded areas as dark blue. A water mask (light blue), created using TM band 5 data from July 15, 1986 and which identifies the rivers' boundaries during a year of average rainfall, was superimposed onto the background image.



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SPOT DATA FUSION WASHINGTON D.C.



10M PANCHROMATIC

20M MULTISPECTRAL
RESAMPLED TO 10M



PANCHROMATIC MERGED WITH MULTISPECTRAL

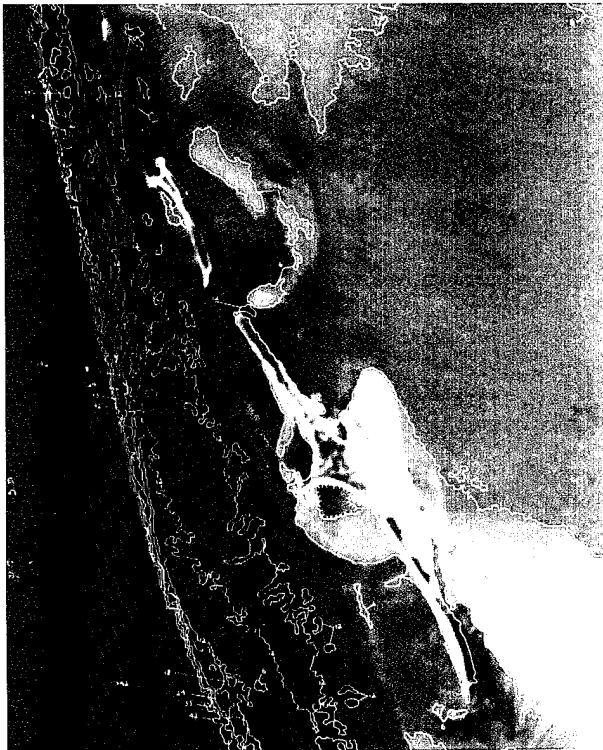
Copyright 1987 CNES



Image Processing by the Environmental
Research Institute of Michigan
Ann Arbor, Michigan

Bathymetric Extraction

North Cat Cay, Bahamas



Contoured Depth Image
(Depths in Feet)



Color-Coded Depth Image

DEPTHS (ft)

1 - 3
4 - 6
7 - 9
10 - 12
13 - 18
19 - 24
25 - 33
34 - 42
> 42

Images Derived from Processing of TM Bands 1, 2 and 3

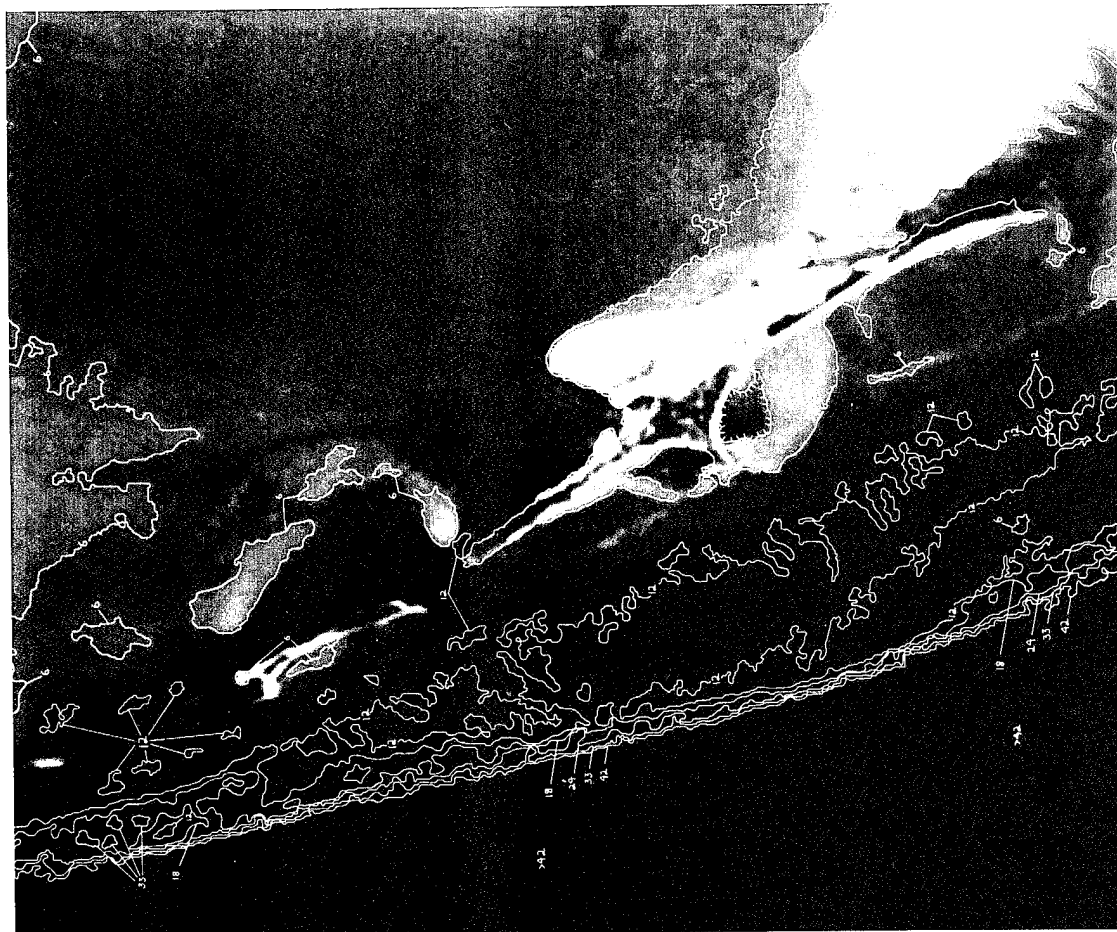


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LANDSAT TM CONTOURED DEPTH IMAGE

North Cat Cay, Bahamas

Path / Row: 14 / 42 30 January 1986 ID. 50700 15105



• Depths in feet

• Average absolute error for extracted depths: 1.77 feet

• Maximum depth calculated: 42 feet

• Maximum depth of field data available for accuracy assessment: 32 feet



1 1/2 0 1 Miles

Tampa



Kennedy Space Center

